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HUMAN ISSUES IN MANUFACTURING TECHNOLOGY

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13. ABSTRACT *(Maximum 200 words)*

This report provides insight into human-centered issues of manufacturing. The information contained in this report presents information derived from current literature and limited expert opinion from government and industrial experts.

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Summary

When manufacturing modernization is mentioned, often space-age advanced technology, robots, automated equipment, and computer screens come to mind. Manufacturing change also changes people: their jobs, their motivation, how they see themselves in the enterprise, how they participate, how they are imbedded in the process, and how they improve it.

The study examines the relationship between human issues and the success of advanced manufacturing technology and integration technology applications. Human issues, as used here, includes human factors, job design, training and motivation, and human engineering of both equipment and processes.

Since modernization includes so many factors to be changed simultaneously, it is often a precarious path with partial successes and partial failures. Modernization projects have success rates of only about 30 percent.

Only the independent parameters of the manufacturing enterprise can be controlled to implement modernization plans and to improve productivity, quality, and competitiveness. The independent parameters are: (1) Business Goals and Objectives, (2) Personnel Policies, (3) Culture, (4) Environmental Factors, and (5) Fiscal Accounting Practices. These parameters are defined in the report. Each of the independent parameters has human issue components and two are composed principally of human issues. Thus, human issues are crucial to successful modernization programs.

The effort defined a new domain of advanced manufacturing systems: the human issues. The study defines additional research needed to complete and refine the independent parameters and improve the understanding of human issues in the modernization process. Also the study underscores the opportunity to immediately apply and benefit from human issues technology that is already known.

Human Issues in MANTECH

Preface

Advanced manufacturing technology (MANTECH) brings to mind the image of robots working in flexible manufacturing cells, automatic conveyance systems, automated management systems, production data and status on computer screens, and one automatic process after another. In manufacturing systems, as in management information systems and maintenance systems, the technology is rapidly changing and, as a result, the role of humans is changing just as rapidly. Humans continue to be essential to the operation, the maintenance, and the improvement of the advanced systems. However, their responsibilities, training requirements, and job designs are changing; they are not the same as in mass production systems of the recent past.

This effort is part of a program to examine the changing role of humans and the resulting effect on the ability of the Air Force to acquire, modernize, and maintain systems necessary to accomplish its mission.

I. EXECUTIVE SUMMARY

Why isn't the United States (U.S.) doing better in competitive, world-class manufacturing? This MacAulay-Brown, Inc. (MacB) study verifies that neglecting human issues is a major reason.

This study began with the hypothesis that human issues are crucia! to advanced manufacturing technology (AMT) and integration technology (IT), but are being neglected in this country. The hypothesis resulted from an antecedent research effort conducted by MacB which examined how human issues are incorporated into manufacturing modernization. Human issues, as used here, include human factors, job design, training and motivation, and human engineering of both equipment and processes. The conclusion: human issues are critical to AMT and IT and are likely to be catalysts, enabling the quality and performance promised by manufacturing modernization investments.

The intent of this Human Issues in *Manufacturing Technology* (MANTECH) study was to test the hypothesis, generate the rationale, and develop the plan to augment current AMT and IT practice with the necessary human issues. Two specific questions are:

(1) What human issues are crucial to MANTECH and IT?

(2) How should human considerations be systematically incorporated into MANTECH and IT?

A. Human Issues Crucial to MANTECH and IT Success

There is evidence throughout this report that human issues are crucial to modernization success and increased productivity. This conclusion is derived from expert opinion, theoretical conjecture, and successful and unsuccessful modernization experiences. There is no conflict around the world or with different cultures. Apparently, neither MANTECH nor IT are successful when defined to be only high technology. This technological myopia meads to a solution for the technology problem and a 70 percent failure rate for modernization programs. The key to success is to blend humans and machines to enhance the productive and creative potential of humans, rather than imitate their abilities with expensive alternatives, reduce them to

machines, or even remove them from production entirely. Examples of these points are contained throughout this report.

B. Model for the Modernization Process

In this report, change or modernization is referred to as a process. A formal analytic model has been devised to represent the psocess and to define its beginning and end states. Modernization and the model are discussed in Section IV of this report. The model provides insight into the process of improving the productivity in a manufacturing enterprise and gives a gramework to the role of human issues.

C. Important Human Issues

After conducting this study, two findings stand out:

(1) Human issues are most important when they are part of the entire modernizatioo picture.

(2) There is a wealth of extant information on human issues that can now be applied to improve manufacturing.

First and foremost, human issues are part of the entire manufacturing endeavor; they are an integral part of integrated manufacturing and MANTECH. As illustrated by the model (described in Section IV), human issues are part of business goals, objectives, and culture. They are altered by and influence the environment, and are a part and function of the attributes and parameters of the manufacturing enterprise. Thus, human issues are part of the AMT and IT modernization plans. For human issues to play their crucial part, they must be handled with the rest of the MANTECH issues. Accordingly, our recommendations and proposed plan incorporate human issues as part of the solution, one of the issues, and one of the technologies that must be worked together. Managers and planners should not be concerned with human issues as such, but should address the way the organization, people, culture, and technology can be used to achieve business goals.

Second, we must use what we know. There are books and data bases filled with information on human issues in many applications and situations including manufacturing. The Engineering Data Compendium (Boff et al., 1988) and the Handbook of Perception and Human Performance (Boff et al., 1986) are examples. However, during our research we found many instances in which the data and principles had not been used. The results were unnecessary failures and mistakes. Therefore, our plan, contained in the Appendix, suggests tasks which begin applying human engineering and other current data immediately.

D. Plan for Human Issues in MANTECH

Our Human Issues in MANTECH (HUMANTECH) Plan, recommends a variety of tasks which encompass the human issues and needs to be addressed. Application tasks will be implemented by an Air Logistics Center (ALC) and a workshop will be conducted on the various accounting systems presently being used to measure the advantages of modernization techniques. Some areas in which fundamental data are not available and exploratory development programs would help are listed. Human issues are part of integration; there is a need to prototype, test, and validate concepts in an integrated environment. For this purpose, HUMANTECH Development Facility has been proposed.

The Ohio Advanced Technology Center (OATC) has been formed to transition technology between Wright-Patterson Air Force Base (WPAFB) and Ohio industry. At present, committee members at OATC select a program from existing programs presently being conducted at MANTECH and evaluate them for human issues consideration.

The Program for Regional Improvement Services for Small Manufacturers (PRISSM) is beginning its second phase. Teams of experts will visit small manufacturers in the Cincinnati-Dayton region to advise them on improving manufacturing productivity. Since PRISSM is a program to transition modernization technologies, it provides an excellent opportunity to include human issues as one of these necessary technologies.

The European Strategic Programme for Research and Development in Information Technology (ESPRIT) is a large, multi-technology program. ESPRIT was started several years ago; therefore, data and experience are available to be transitioned. This will satisfy a portion of the objectives of the HUMANTECH program.

E. Scope of Study

This four-month study was conducted by MacB and a Wright State University faculty and student team. The total effort required1263 person-hours or about 0.6 of a person-year.

After conducting this study, we agree with Robert H. Hayes and Kim B. Clark (1986) who said, "It is now time for concrete action on a practical level: action to change facilities, update processing technologies, adjust work-force practices, and perfect information and management systems."

II. PURPOSE OF STUDY

A. Program Objective

The objective of this program was to conduct a literature search, consult with government and industry experts, analyze the findings, and develop a HUMANTECH program plan. The study included both AMT and IT. Human issues are skills, organization, and technology which includes human factors, organizational infrastructure, and cultural barriers.

B. Reason for Study

U.S. industry is no longer the standard by which others are compared in the competitive world of manufacturing. The U.S. does not produce the best products for the best price; therefore, we are losing market share in many product areas to other world-class manufacturers. This is not a new phenomenon, it has been occurring for more than fifteen years.

Why? Since the need for improvement is so widely accepted and the failures so broadly advertised, why haven't large chunks of U.S. industry become world-

class manufacturers? Many companies are trying to become more competitive. Some companies are successfully making the shift: NCR, Xerox, Black & Decker, Rubbermaid, Harley Davidson, Mead, and others. However, there is also a long list of failures, firms that cannot seem to become competitive. Does U.S. industry not know how to improve either as rapidly or consistently as necessary? Do industry leaders not know how to systematically and confidently change manufacturing to become more competitive? What is the problem? Is it management theory or practice? Science and technology? Culture?

This report, discusses change from one kind of manufacturing to another. World successes teach that change is a process, not an event. For manufacturing, change is an evolving, learning process; it is not stationary.

1. Essential Human Issues

Many companies are changing, but some change more effectively than others. Kidd (1991) reports, "One study of manufacturing firms in the United Kingdom has shown that of the firms examined, all of them managed to achieve technical success. In other words, all the companies examined got their technical systems installed and fully operational, with all operating problems resolved. However, only 86% of these companies achieved increases in productivity, and just over 57% realized other benefits such as improved flexibility, quality, throughput times, due date performance, etc. Amazingly, only 14% of these companies managed to improve their competitiveness."

These companies intended to change for the better; that is, become more competitive. Why did only 14 percent improve their competitiveness? What is missing? At present, the prevailing response to this competitive manufacturing challenge is to depend only on the extensive use of technology. "This 'technological parochialism' has only recently been identified as one of the major reasons for the relatively low industrial performance in the United States. . . . In light of these problems, alternative concepts are gaining attention, which aim primarily at reorganizing the production process in order to make extensive use of human skills rather than tasking technology as a panacea" (Brodner 1991).

The changes impact the people, their jobs, how they are motivated, how they see themselves in the enterprise, how they participate in all activities, how they are imbedded in the process, and how they continue to improve it (e.g., necessary additional training, the organizational and labor flexibility required, etc.). Thus, a predominant impact of modernization is the difference in the way people participate in all things in the enterprise. "The biggest gains result from this change in the way people are used; including the 'never ending improvement' which is uniquely a people dependent process" (Ashton and Cook, 1989). The fundamental question is how to use people in a modern manufacturing plant.

2. Future Plan

The previous sections have illustrated the crucial role of human issues in achieving successful manufacturing modernization. The remainder of this report discusses the most important needs and issues, develops the rationale for a plan, and describes a plan for HUMANTECH.

III. DESCRIPTION OF STUDY

The study effort was structured to respond to the following two questions:

(1) What human issues are critical to MANTECH and IT?

(2) How should human issues be systematically incorporated into MANTECH and IT?

This effort, which includes the objective to provide the MANTECH program with a plan of action, extends earlier MacB research. This plan would lead to the development of programs that would result in the acceptance of human considerations as a crucial factor when implementing advanced manufacturing systems.

The tasks undertaken during the course of this study were:

(1) a comprehensive worldwide literature review;

(2) identifying, analyzing, and placing in perspective the relationship between human considerations and the AMT and IT successes in industry;

(3) examining and analyzing the potential relationship of HUMANTECH to AMT/IT programs in Europe, Japan, the Air Force, the Navy, National Institute of Science and Technology (NIST), Defense Advanced Research Projects Agency (DARPA), and the aerospace industry; and

(4) development of a comprehensive plan for the HUMANTECH program.

A. Styles of Production

In this section, three styles of production are defined and contrasted to illustrate the changing role of humans in manufacturing during the last hundred years. We show that humans, both as workers and customers, have been central to the changing role.

1. Craft Production

Craft production, the only production method prior to Henry Ford's manufacturing breakthrough in the early 1900s, has its roots in the apprentice-master system developed in Europe during the Renaissance. Craftsmen were responsible not only for the final products they sold, but also for the development of the tools they used. Toolmakers were at the pinnacle of the craft-production system.

Craft-production methods relied upon highly skilled workers who used simple but flexible tools (Womack et al., 1990). These workers interacted directly with the customer, who directly influenced the design and amenities of uhe final product. Skilled workers psoduced low volumes of a variety of individually tailored, high-quality products. Craftsmen took pride in their work, achieved high levels of satisfaction, received new orders by word of mouth referrals, and participated in multiple aspects of product development. Individual craftsmen were actively sought by competitors.

Figure III-1 shows a craft-production approach to the manufacturing of a complex product: the violin. To produce a violin, the craftsman performs a series of steps himself, such as sawing, planing, carving, gluing, assembling, finishing, and tuning the instrument. When completed, each violin has characteristics unique to its materials, construction, and customer preferences.

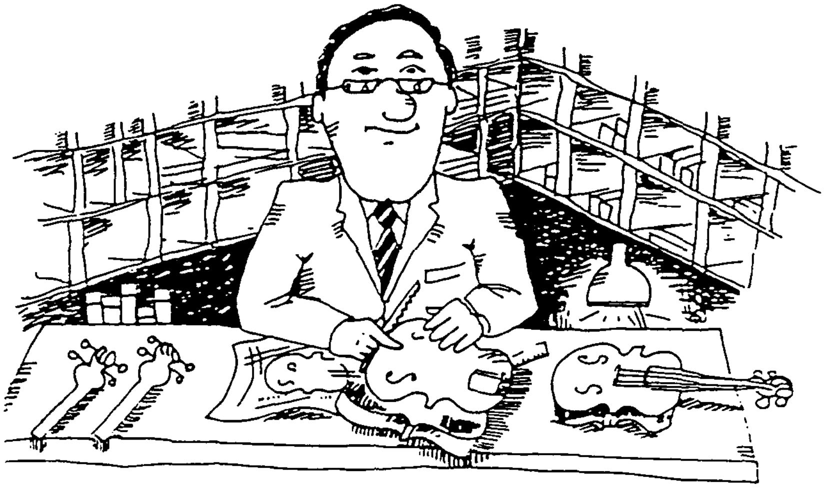

FIGURE III-1. Craft Production: Skilled and Motivated Individuals Building Quality Products

2. Mass Production

Over the last 80 years, mass production, originated by Henry Ford in 1910, has become the predominant manufacturing method in the world. A natural offshoot of the Industrial Revolution of the 1800s, this method fundamentally changed how products were made and how humans were used to make them.

Mass-production methods rely upon highly specialized, expensive, yet inherently "dumb" machines to produce large volumes of standardized products. Humans are separated into two groups: narrowly skilled professional designers, managers, and sales persons; and the unskilled/semiskilled worker on the production line.

These workers participated in the production process only as needed, either to assist the machines or perform tasks for which machines had not yet been designed. The dark vision of a society of workers catering to machines was the subject of the science fiction move "Metropolis," which was produced in 1926. "The film balances two mechanical miracles and they are both man-eaters. . . . With an insensitivity that is difficult to credit, the two most powerful men in the city decide that one machine can service the other and that it will consequently no longer be necessary to maintain Metropolis' vast army of workers. They will be replaced by robots ('in the image of man,' exults their inventor, 'machines that will never make mistakes!')" Science Fiction Movies, 1976).

Due to standardization, qroducts of mass production do not have much variety. The objective is to get as many pieces down the assembly line as possible. The measure of goodness is quantity rather than quality or customer satisfaction. Workers are assigned to service the mass-production line and perform tedious, unfulfilling tasks. Since they do standard jobs (e.g., attaching six screws), they can be dismissed and replaced as necessary. No one is responsible for any product; workers have little status or feeling of accomplishment.

Figure III-2 depicts a mass-production system. In this situation, the workers have lost interest in the products they are producing. Production tasks are simple, repetitive, and boring. Absenteeism may be high. Very narrow job descriptions dictate workers' roles.

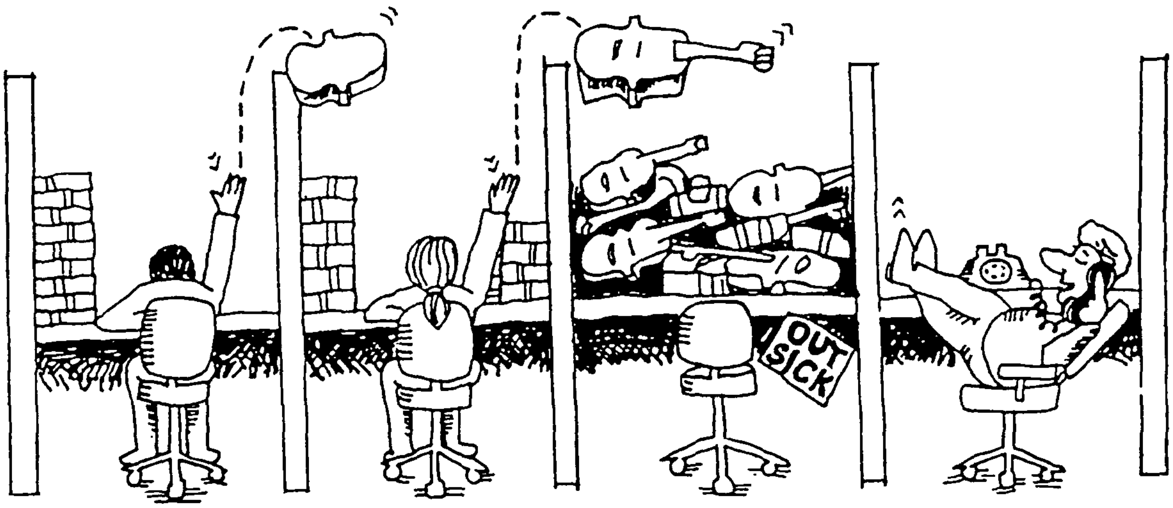

FIGURE III-2. Mass Production: Unskilled, Unmotivated Workers Cater to the Demands of the Line

3. Lean Production

Lean production was pioneered in Japan by Eiji Toyoda and Taiichi Ohno when they established the Toyota car company (Womack et al., 1990). It took Toyoda many years to put in place the processes he felt were critical to production. Lean production blends selected elements of both craft and mass production into a form that is beneficial to humans as workers, customers, and business owners.

This blending of elements is illustrated in Figure III-3. In lean production, teams of multiskilled workers are used at all levels of the enterprise. Each team is responsible for a product and its quality; therefore, that team is provided data to measure its own performance. The team is also responsible for improving its performance. Since they are responsible for their products, the team members are the only ones that need the quality or production data. This decreases data production, which in turn decreases costs. The number of people who actually handle the product is increased, but the overall work force is reduced (lean). Large vertical bureaucracies are replaced by flat management structures, and highly motivated and satisfied teams of workers (Figure III-4). Highly automated machines and robotic systems are used in lean production to assist humans responsible for developing and producing the product.

B. Significance of Human Issues to MANTECH

MacB conducted a HUMANTECH study during the spring and summer of 1990 which provided the motivation for uhis contract effort. The study, which consisted of a comprehensive literature review, concluded that human issues were more consequential to manufacturing modernization than was realized in the U.S. Manufacturing improvement in the U.S is often limited to technological improvements; operators and management are expected to adapt to such changes. This section highlights the significance of human issues to MANTECH and to competitive manufacturing in this country.

1. Unrealized Expected Gain from Modernization

"The state-of-the-art factories in the United States auto industry are not performing as planned" (Unterweger, 1986). Unterweger proceeds with the following comparison to make his point. Both plants are modern, automated, machine-centered production systems.

General Motors' Hamtramck showcase plant in Detroit
Cost $600 million
5,000 workers
220,000 cars/year

Mazda's plant just south of Detroit
Cost $450 million
3,500 workers
240,000 cars/year

What essential differences cause such a large discrepancy in performance? Unterweger argues that it is human issues; people must be included in modern production for "efficiency, flexibility, innovation, integration, and cost effectiveness in evolutionary modernization." He reaches his conclusions by comparing U.S. modernization approaches to those used in Japan and Sweden. Unterweger provides four common elements from the Japanese and Swedish approaches that contrast with the U.S. approach:

(1) Hardware plays a subordinate role to organizational or human factors.

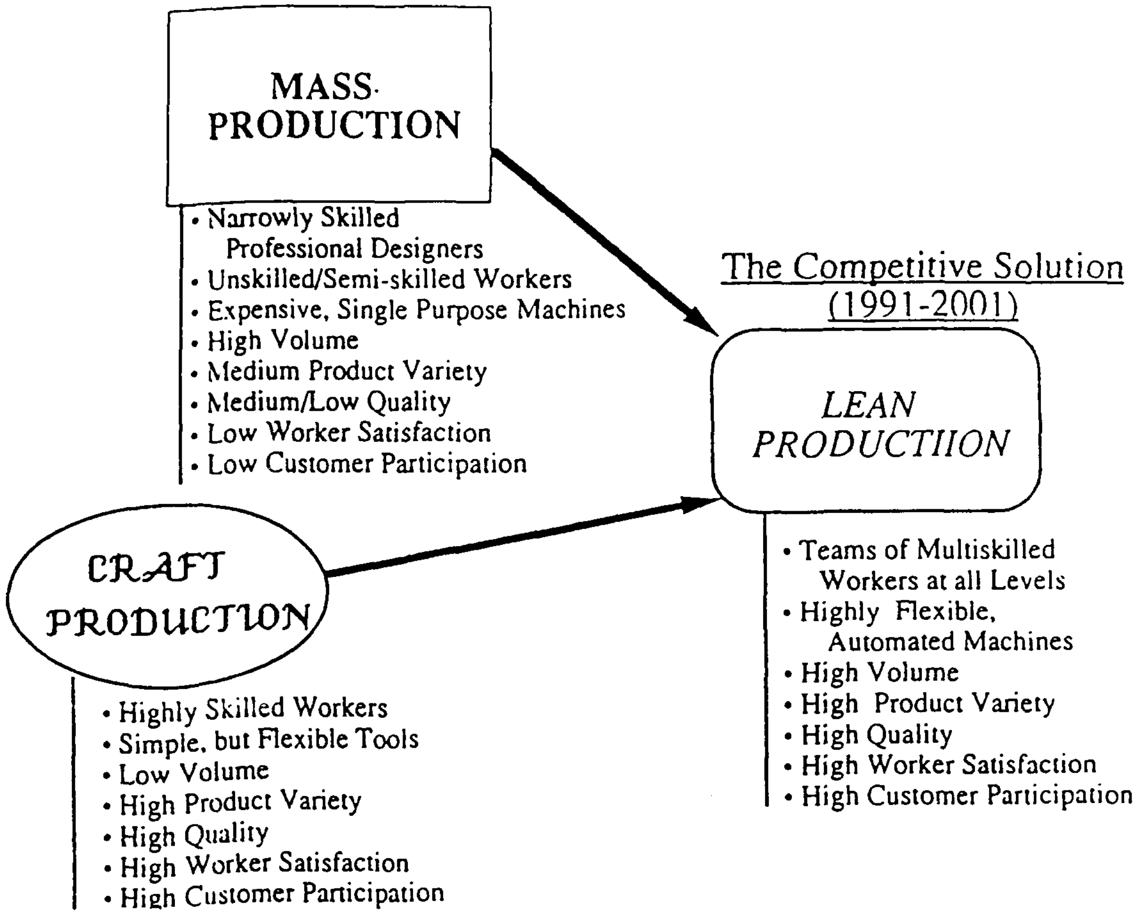

FIGURE III-3. **Lean Production: The Competitive Solution**

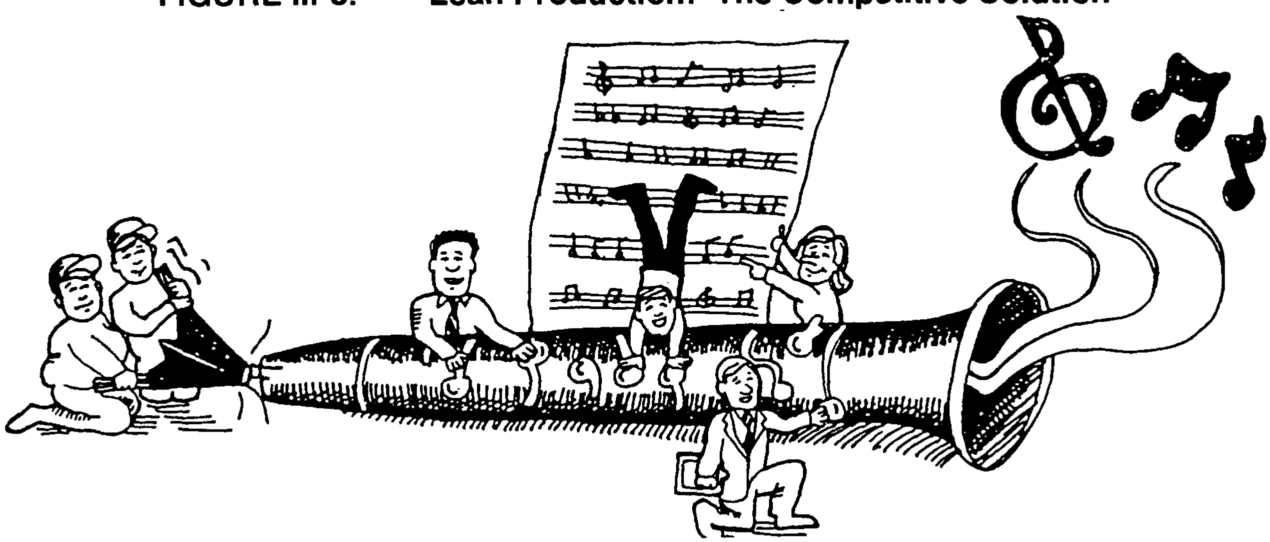

FIGURE III-4. **Lean Production: Skilled and Motivated Teams Build Quality Products**

(2) The current production system is the result of a long development in which relatively small changes are used to gradually improve the process.

(3) The technical system and the work organization were developed in step with one another.

(4) "There is a bias towards simplicity in the technical system.

These countries emphasize human issues and organizational factors first. Often in the U.S., manufacturing is designed with human and organizational factors arranged around the technological solution. The U.S. has a bias for the technical system, assuming it will be the productive one. Experience has proved that this assumption is wrong.

"Unfortunately, many [computer-integrated manufacturing (CIM)] implementations have not produced the desired results. Some of the problems with these less-than-success stories may be caused by the human aspects of the CIM implementation. ... Zylstra (1987) discusses the changes and gains a company can expect with CIM, then tries to explain the cause of the less-than-success stories. Typically, the human aspects of these CIM phases [are] not addressed until problems arise or unless the 'system' does not function properly." That is, the less-than-successful stories occur when the human component of CIM is neglected.

Zylstra's article makes another valuable point: the problem of basing production expectations on the analysis of only the automated portion of CIM.

> Without the human element of the operating condition, the system performance can only be determined from the fully automatic mode (if it can operate with the "lights out"). This automation view of CIM misses the effects of system problems, manually tended operations, new product changeovers, maintenance programs, and other human intervention that will not be understood or included in the CIM plans.

Since "system problems" account for about 50 percent of the enterprise costs, it is misleading and often disappointing to base CIM expectations and plans on only the automated portion of an enterprise operation.

Many references that incorporated human issues as an essential element of the manufacturing change originate in foreign journals or at conferences. P. Gerencser and A. Veszi, members of the Computer and Automation Institute, Hungarian Academy of Science, state, "In practice, the introduction of complex systems often caused disappointment" (Gerencser and Veszi, 1986). Their prescription for avoiding the disappointment is to blend technology and human resources with a systems analysis of both the flexible manufacturing system (FMS) and its environment.

Jaikumar (1986) sought to determine why the U.S. was not realizing the expected gain from modernization. From a study of more than half the installed systems in both Japan and the U.S., he found that each FMS in Japan produces an average of 93 different parts; systems in the U.S. produce only ten. Each installation in the United States produces an average of 1727 units for every part it makes; in Japan, the comparable number is 258. Jaikumar sums up his observations:

> These figures tell a terrible tale: American companies are using computerized manufacturing for the same old-fashioned, high-volume, low-variety production they have always pursued.

The conclusion is that even though U.S. manufacturers buy FMS equipment, they use it so poorly that the technology gap with Japan is widening; Japan turns out almost ten times as many parts per machine. Jaikumar notes, "Having the technology and using it well are two different things." Jaikumar feels that the FMS environment makes the planning function of process engineers the most important function in the plant. The emphasis is again on the process and the goals of the organization.

Farver (1990), in an article on the Focus Factory, cites an example that did realize the gain from modernization:

> We believe our production uptime record is also the result of upgrading the role of our production workers.
>
> People. Today more than ever it seems, manufacturing engineers and managers are realizing that perhaps the greatest single factor contributing to the success of an automation endeavor is the people involved. At our plant, we view the factory-of-the-future concept as more than operations that are computer-controlled. We believe our

> success is attributable more to the involvement of employees working together to improve productivity.
>
> ... [B]ut the biggest contribution is made by the employees themselves.
>
> Factory of the future? By no means a "lights-out" concept for us. People are key!

Many organizations are not realizing the gain expected from modernization programs. Experience indicates that neglecting human issues is at meast part of the reason. Human issues are a crucial component of MANTECH.

2. Human Issues More Important Overseas

ESPRIT has allocated four million pounds sterling to develop human-centered manufacturing in the industrial setting. Bullinger et al. (1989) report, "This project 'Human Factors in Information Technology' (HUFIT) is an extensive project of cooperation in ... ESPRIT ..., involving eleven companies and research institutes in eight European countries. The project has two major objectives: it aims at improving the design process of information technology products by increasing the awareness of Human Factors issues and by providing methods and tools for a user-oriented design. The second major objective is to further develop user interface techniques, especially for multimedia and multimodal interfaces and to provide tools for prototyping, and implementation of these interfaces."

The PRISSM Phase I Final Report (1990) states, "Japan budgets over $500 million annually to finance 150 Technology Assistance Centers chartered specifically to assist their small manufacturers technologically and managerially so they can be highly competitive in the world arena. This stands in stark contrast to the United States where there is no national mandate to preserve the strength and competitiveness of the national small manufacturing base. Collectively, this nation allocates only $60 million per year ($30 to $50 million from the state government and $10 million from the federal government) in a splintered approach with no national strategy."

Although it is recognized that foreign governments spend far more on manufacturing technology development than the U.S. government, it is not as widely recognized that much of the foreign spending is targeted toward human issues. Foreign governments spend far more on human issues than does the U.S.

3. Automated Manufacturing is Manned

Human issues are an element of manufacturing, even of totally automated manufacturing. Seifert and Rijnsdorp (1982) make the point:

> The trend towards a high degree of automation is often advocated by stressing the limitations of human beings and the superiority of automatic devices. However, ultimately man is reintroduced into the system as a supervisor, evidently to cope with shortcomings in automation, and possibly, systems design. This is one of the ironies of automation.

Seifert and Rijnsdorp confirm that automation for automation's sake or automation to replace people generally fails. Automation does not necessarily provide increased quality or productivity.

Another interesting point is made by the same authors: "... [I]n trying to separate human and system errors, one needs to define which owns the human errors in the design of the system. We have only separated the operators from the designers and then only if operators were not part of the design team, which itself may be an error." Systems can be designed to use humans and still have low error and rework rates. In an instance of high error rates, new thinking may be required, but automation is not a compelling solution.

4. Human Issues in Modernization of Small Business

Human issues are more crucial for small companies. Small businesses often capitalize on the flexibility, ingenuity, and mobility of employees. Many of these businesses use older equipment and technology than is appropriate for

the advanced technology solutions, with the inherent cost and risk, would often

disfigure the company process and culture.

The national programs in the U.S. do not attempt to transition technology to the special situation represented by small businesses. For example, the National Institute of Science and Technology (NIST) has three regional centers in Ohio, South Carolina, and upstate New York. These centers are designed to transition technology to industry; however, there may not be enough attention to small companies in that process. Since NIST is designed to benefit strong companies which use state-of-the-art technology, more than 90 percent of small manufacturers who do not need that mevel of advanced equipment are eliminated (Carey and Schiller,1990). Carey and Schiller also note:

> The Congressional Office of Technology Assessment estimates that Japan's government spends $31 billion on technology extension and loans to small business each year. The U.S. total, including state and local spending, is more like $250 million. And it reaches only about 2% of the nation's 360,000 small manufacturers. That makes technology extension just one more area in which America is behind.

5. Human Issues in Computer-Integrated Manufacturing

"Integrated" is the pivotal word in computer-integrated manufacturing. Integration brings objects together; for a manufacturing enterprise that means bringing together the enterprise. In this application, "integrated" brings together the elements of integrated manufacturing including the human.

George Sibbald (1986) offers a general overview of CIM: "CIM's key word is integration, which mandates an extended scope, taking a company-wide strategically focused view." Sibbald examines several points of view, including executive, technical, and unmet needs. He describes how to implement a CIM program that includes flow diagrams of actions and planning. Yet, one of his final points is: "The missing element of U.S. reindustrialization in the 'information age' has been Human Engineering or the innovative/creative culture."

Human engineering and human factors are crucial elements of CIM, but there are also other critical human issues. Parsons (1986) notes that the field of robotics includes human factors, safety, training, software design, job design,

management/organization impact, industrial relations, occupational effects, and social impact.

Human issues are a necessary element of CIM. If they are absent, the CIM application will be less effective.

6. Education and Training for Manufacturing

Manufacturing employees entering the work force are less capable because of the decreasing competence of high school graduates and the higher incidence of high school dropouts. Meanwhile, there is highly advanced technology in manufacturing and, in general, in the work place. The combination of reduced competence and advanced technology portends a future lack of qualified manufacturing employees.

David Lichtinger, plant manager for Lord Corporation's aerospace products plant in Dayton, believes these problems exist today (Stricharchuk, 1991). Lichtinger says that attracting trainable workers from area high schools is nearly impossible. "The high school graduates who go through Lord's screening often have only ninth- or tenth-grade skills--not enough to operate sophisticated machines."

Pat Ordovensky (1991) writes: "The results of a federal study portray a nation of students who are not doing well in mathematics." The study reports the following findings.

(1) Most students can't meet on-the-job demands for problem solving.

(2) Only 46% of high school seniors can solve problems involving fractions and decimals. Only 5% are ready for college math.

(3) Only 66% of eighth-graders and 77% of 12th-graders correctly totaled the cost of soup, burger, fries, and cola on a restaurant menu.

Engineering education could also use some improvement. W. M. Spurgeon (Director, Manufacturing Engineering Program, University of Michigan) summarized at the conclusion of a 1986 Advances in Industrial Engineering Conference in the Netherlands: "It was disappointing that only one author referred to what can be

accomplished if the potentialities of humans in production systems can be utilized more fully.... Engineers continue to be thing oriented more than people oriented, to neglect human factors in their product and workplace designs, and to forget what people can accomplish in a production system if they are considered to be an important part of the system."

Engineers are often taught today's solutions rather than how to find new solutions to today's problems. Humans are certainly part of manufacturing, yet their crucial role is not preseuted/taught to those who will be developing future manufacturing.

High schools and colleges are deficient in providing appropriate curriculums for the demands of modern manufacturing. In the future, manufacturing enterprises themselves will neeu to provide more training in and more effort on the design of effective and creative uses of employees.

7. The Human Use of Human Beings

If designers and managers are more interested in the use of technology than in the use of people, people may be poorly used and actually abused by the system implementation.

A recent television program provided a modern example of the poorest possible combination of technology and humans--developed in the name of advanced technology. Whenever a phone call is made to American Airlines, it is routed to a central answering operation. The operators are lined up shoulder-to-shoulder, facing the computer terminal against an otherwise blank wall. Each operator is wearing a headset. At one end of the row of operators, the supervisor watches through a window from an elevated office. The operators are not allowed to talk to each other, and uhey can be monitored through the headsets. They have to ask to go to the bathroom and the amount of time they take is recorded. The computer tracks each call and the time between calls. They are expected to take less than nine seconds for each call; if they take longer their rating is reduced. If they take too long between calls, their rating is again reduced and the supervisor may ask for an explanation. The operators each receive an evaluation at the end of the day. That is their only feedback ever

unless their work is unacceptable. The system is designed with the assumption that the workers are dumb, rebellious, and not trying to do a good job. The operators are in a very high-stress situation and have the expected reactions. There is frequent absenteeism, low morale, and physical complaints involving arm, back, and neck problems. The technology is being used to drive and manage a "herd" of humans. It is hard to believe that the American Airlines customer on the phone is getting excellent, world-class service.

However, the same technology (maybe even the same equipment) coupled with a different point of view could result in a system that would keep employees well-informed, provide support systems to help them give better answers, give employees the responsibility for providing excellent answers and a positive image of American Airlines, allow them to work as a team to improve customer service, and overall, produce enthusiastic employees. The problem is not with employees or the technology. American Airlines has chosen to develop a system that abuses both their employees and their customers.

T. Martin (1982), with the Manufacturing Technologies Program Management, Federal Republic of Germany, claims that computers are integral system components that determine the quality of work of operators in industrial production. He says:

> The development of industrial production is characterized by growing mechanization, increasing automation and work becoming more and more fragmented and hierarchically organized. The fragments of work being left to one worker require a narrower range of skill. The content of work actually performed at site (where the workplace is) is further reduced by taking the work planning and preparation away from it (separation of thinking from doing). An example of this is the conventional NC [numerically controlled] machine tool operation being limited machine loading and unloading and monitoring, leading to harmful qualitative underload of the work person.... [F]urther technical changes may lead to de-skilling of most workers; physical and mental strains may rather grow .... Yes, there is an urgent need for considering human criteria in the early phase of requirements specifications....

The flavor here was that it is the manufacturing process dehumanizing jobs which has contributed to the narrowing and

deterioration of workers' capabilities. This leads to lowering the requirements for the next round of design and automation of factories.

Neglecting human issues causes a deteriorating cycle for people and jobs. In this period of history and with this technology, we are in a position to use computers and the new technology to improve the lot of man rather than degrade it. Norbert Wiener, in his book The Human Use of Human Beings, said:

> In my opinion, any utilization of a human being is degradation and waste if it asks for less and expects from him less than his full capacities. It is a degradation to chain man to a thwart and use him as a source of energy; but is almost as great a degradation to set him in a factory to a perpetually reiterating task which claims less than a millionth of the capabilities of his brain.

We must be aware of human issues in order to achieve the best human use of human beings in MANTECH. Including human issues in system design means we, as a country or technologists, must do our best. Neglecting human issues means doing less than our best for human beings.

8. With Advanced Manufacturing Technology, People Are More Important

The first impression may be that as modern technology (robotics, computers, networks, automatic control and conveyance, etc.) is introduced into a manufacturing facility, people become less important. The opposite is true. Richard Walton, author of "Resource Practices for Implementing Advanced Manufacturing Technology," in conjunction with Gerald Susman (Walton and Susman, 1987) wrote an article on this study. They note:

> Look at what happens when ...[AMT]... is introduced into a workplace. In plant after plant we see:
>
> (1) Closer interdependence among activities.
>
> (2) Different skill requirements - usually higher average skill levels.
>
> (3) More immediate - and more costly - consequences of any malfunction.
>
> (4) Output more sensitive to variations in human skills, knowledge, and attitudes, and to mental effort rather than physical effort.

(5) More dynamism, that is, continual change and development.
(6) Higher capital investment per employee and fewer employees responsible for a particular product, part, or process."

Each of these six conclusions indicates that workers are more important and valuable when AMT is introduced into the work place, particularly those working oo the shop floor as part of the manufacturing process. They have more information, are allowed more control over the process, are better informed about the process, and determine the production efficiency.

9. "Technocentric" vs "Anthropocentric" Modernization Approaches

Brodner (1982) coined two definitions to show that including human issues in MANTECH requires a little additional thought about how the system will be used. (Brodner is with Manufacturing Technologies Program Management, Federal Republic of Germany.) As part of anthropocentric design, system alternatives are generated and span the possibilities of human participation in the system. There is a methodological problem because the alternatives are difficult to evaluate. On the other hand, human design alternatives are generally broad, without rapidly changing utility in the vicinity of the maxima. Therefore, there is room for alternatives in the technical and performance specification which still provide the options to explore human design in the design process. The following definitions and the cartoon in Figure III-5 provide a visualization of the two approaches.

> Technocentric Approach: Man-machine systems are usually analyzed and designed based on functional requirements and the technological state of the art, where man has to take over those functions that are not yet solved technically. The systems are evaluated on the basis of technical functionality, feasibility, and economic whereas man is regarded as being reduced to the functions he can perform better than the machine.

> Anthropocentric Approach: Man acts consciously and is able to plan and control his actions even under uncertainty. This requires that the man-machine system be analyzed and designed such that man is able to interact with the machine purposefully. Therefore, the division of functions between man and machine, and the functional requirements of the technical system and the man-machine interface,

must be derived from and adjusted to the specific capabilities of man to produce certain results, and his limitations to bear loads. To evaluate those systems, criteria for human work design (such as work safety, suitable work loads, work contents, and margins of action), besides technical feasibility and reliability, must be considered.

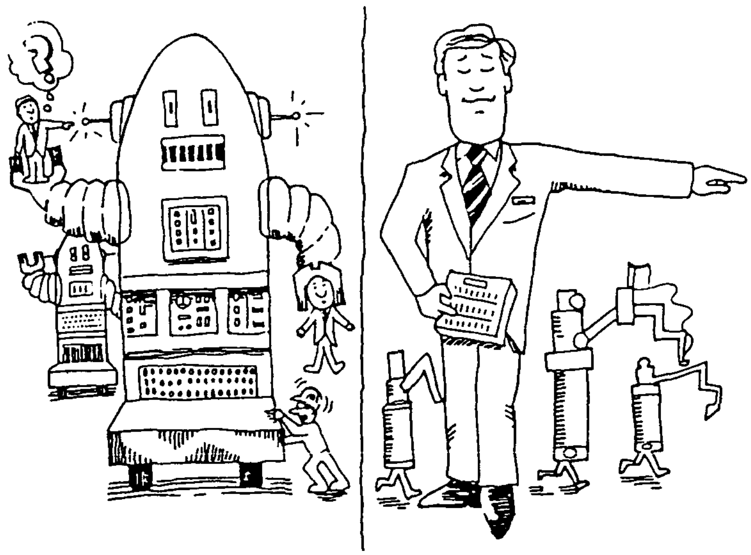

FIGURE III-5. The Technocentric and Anthropocentric Perspectives

Anthropocentric, or human-centered design as it is more commonly called, requires additional effort in the design phase. However, the payoff is a design that allows workers to contribute to manufacturing competitiveness. Employees are not locked into jobs where they mindlessly service the technology contraptions; rather, they are asked to think, plan, and contribute to continual improvement.

10. Emerging Theory of Manufacturing

A revolution is taking place in manufacturing in addition to technology. There is a changing social organization in the factory that is refocusing the factory operation around the worker. Peter Drucker (1990) made the observation:

> Statistical Quality Control (SQC) is changing the social organization of the factory.... The module organization of the manufacturing process promises to combine the advantages of standardization and flexibility. Finally, the system's approach embeds the physical process of

making things, that is, manufacturing, in the economic process of business, that is, the business of creating value.

The perspective is: SQC provides feedback to the machine operators so they can control their work. They alone have access to the information. The number of machine operators, those who touch the product as it is being produced, increases. The number of employees who do not touch the product (i.e., overhead positions) decreases. Since the workers that build the product have the responsibility and data necessary to improve, productivity and quality increase.

New measures that reflect the changing responsibilities throughout the manufacturing enterprise are needed. Drucker talks about accounting methods and measures that are essential to the new emerging theory of manufacturing.

The new theories "tackle the conflicts that have most troubled traditional twentieth-century mass-production plants: the conflicts between people and machines, time and money, standardization and flexibility, and functions and systems. The key is that every one of these concepts defines performance as productivity and conceives of manufacturing as the physical process that adds economic value to materials" (Drucker, 1990). Thus, the system variables and parameters are on the same scale with consistent metrics. Manufacturing can have it all without compromise. There can be economical manufacturing without the inflexibility of mass production; and flexible manufacturing that is responsive to customer needs without the cost of custom-made products. The economy of mass production can be combined with flexible manufacturing to provide the best of both.

11. Human Performance of Complex Tasks

In MANTECH decisions in the U.S., there is a strong bias (even an intermediate goal) to replace labor with automated systems. There are two widely cited reasons: (1) reliability and variability of humans, and (2) cost. When one of these reasons is accepted as valid, a modernization program is often defined as an automation program with the belief that improved production will follow. Improved production has not always resulted from such decisions.

Replacing labor with automation is often an expensive process that

does not increase productivity. Kenneth Ludema et al. (1987) state:

> It is often surprising to see the great number of manual or unmechanized operations even in a highly mechanized manufacturing facility. Assembly is often done manually, as is die-setting, machine loading and unloading, inspection, counting of inventory, and even communication. A factory therefore is usually only partly mechanized, and very likely none will ever be completely mechanized. First of all, the cost to mechanize completely is prohibitive. Second, there are some human capabilities involving aesthetics and judgment that will not be profitable to mechanize. After all, consumer products must appeal to the highly varied subjective sense of the consumer, and human judgment is required to determine when products are ready to risk in the marketplace.
>
> But automation is cost-effective only for simple tasks. The majority of humans can readily perform fairly complex tasks, and for moderate pay.... One can discern two aspects of the complexity of a task. One is manual dexterity, or the skill in making complicated movements. The other is in the use of the senses (sight, pressure, sound, feeling of vibration, etc.) in guiding action. Several human senses are used to monitor even the simpler tasks. To integrate only one or two senses with complex motions in robots or other automated machines is very expensive.

Much of the impetus to replace labor as a cost-controlling measure was based on an artifact of the accounting system. Conventional accounting burdened labor with the other indirect costs of operations. Thus reducing labor appeared to reduce cost. It did, of course, but not in a manner that was sensitive to the operation of the enterprise. That is, reducing labor did not increase competitiveness. The focus is now on the emergent area of activity-based cost accounting and other measures that provide visibility into the effectiveness of internal processes.

The more significant MANTECH deliberation is: What is the manufacturing process to use? and, then, To what degree do mechanization, automation, and computerization improve the productivity and performance of the manufacturing processes? The goal must be to achieve a competitive advantage rather than tc replace labor.

12. Information and People

Information and people are the key to future competitive manufacturing. "Operators will spend more time managing the interface than performing touch work" (Smith, 1990). George L. Smith convened a workshop for the National Science Foundation entitled, "A Research Agenda for Production and Service Systems (RAPSS)." The workshop product was not a research plan but a guide for future research. The recommendation: information and people are key factors which should influence the research agenda.

In conclusion, people and human issues are part of manufacturing. Human issues should be a larger part of MANTECH and manufacturing modernization deliberations. In this era, fundamental manufacturing processes are being redefined, from technology to accounting systems and from mass production to lean production. Human issues are a crucial area in which new data, processes, and perspectives are required if U.S. industry is to be competitive in the world market.

C. Study Tasks

1. Literature Review

During a previous research effort, MacB examined the rapidly growing literature dealing with human issues in manufacturing, MANTECH, and advanced manufacturing systems (AMS). This early review documented the importance of human issues in the transition from historic mass-production techniques to implementation of highly productive AMS.

The current study extends the earlier effort into a comprehensive review of the relevant literature. As expected, a massive volume of technical/professional literature exists related to technology, hardware, and systems--from research and development (R&D) to the manufacturing floor. In addition, there is extensive material in the discipline literature. The literature includes journals dealing with electrical, mechanical, industrial, and aeronautical materials; human factors; organization theory; management; and others. The focus of the literature review was provided by the study objective: to place the HUMANTECH in useful perspective.

Two human factors engineering, senior-level students were employed to search and evaluate the literature with the assistance of principal investigators. The data base was derived from technical/professional journals, proceedings from technical conferences, and discussions with experts. The literature coverage was international; in fact, many of the important findings were derived from literature generated in Europe or Japan, or from U.S. sources discussing European and Japanese AMT programs.

The literature research results are incorporated throughout this report. However, some references are particularly significant. One stands out above all others: The Machine That Changed the World (Womack et al., 1990). This book provides excellent insights describing current struggles with conventional mass-production manufacturing and the benefits of lean manufacturing. The text details the results of a five-year, multi national study performed at the Massachusetts Institute of Technology (MIT). Their five-million-dollar study is the most comprehensive research on the automotive industry. The MIT text draws from 116 research monographs prepared by affiliates of the International Motor Vehicle Program. The study is replete with empirical data and comparisons between mass and lean manufacturing. The key objective is to "illustrate the transition from mass to lean production with concrete examples." The book underscores the importance of humans in all phases and aspects of a modern manufacturing enterprise, from business strategy to factory automation.

Another perspective is provided by Joseph J. and Suzy Fucini in Working for the Japanese. This report, the result of a three-year investigation including over 100 interviews with workers, managers, and suppliers, provides insight into the differences between the American and Japanese industrial culture. The target for their study was the state-of-the-art Mazda plant in Flat Rock, Michigan. In addition to their treatment of the difference between the Japanese and American cultures associated with industry, the authors provide an excellent overview of the worker recruiting, selection, and training processes--a human resource acquisition procedure that assures the acquisition of motivated, high-performance production personnel. Again, the role of the human in MANTECH is evident.

In their desire to understand worker attributes and provide direction for optimizing the role of the worker in the manufacturing system, ESPRIT has, in its

brief existence, provided a catalyst for European industry as it transitions to AMT. The research is developing tools and techniques for the design of human/information systems that would be useful in the U.S. ESPRIT is discussed in greater detail later in the study.

Section III.B, Significance of Human Issues to MANTECH, provides additional details and results of the literature search.

2. Related Advanced Manufacturing Technology/Integration Technology Programs

Government, industry, and academic resources are being applied at an increasing rate in response to the need for enhancing the application of AMT. Several countries and government agencies are conducting AMT and IT programs. The Air Force conducts a large multifaceted program managed by the Manufacturing Technology Directorate at WPAFB (which is partially funding this study). NIST has an Automated Manufacturing Research Facility (AMRF) and a series of centers around the country to transition manufacturing technology to industry. The Navy has a Manufacturing Technology Program with Centers of Excellence at the Electronics Manufacturing Productivity Facility (EMPF), at Metalworking Technology, Incorporated (MTI), and at the NIST AMRF. DARPA has a large program in concurrent engineering and other manufacturing technology interests. The National Aeronautics and Space Administration (NASA) is developing a human factors/computer-aided engineering system called Man-Machine Integration Design and Analysis System at the Ames Research Center. This development may impact the definition of an integrated-design environment used in MANTECH.

Japan continues to fund extensive development and transition programs in manufacturing and related technology. The Human Centered Computer Integrated Manufacturing Systems project is a program under ESPRIT.

There are currently 184 organizations calling themselves "manufacturing research centers" throughout the U.S. Over 41 states host such centers; Illinois, Pennsylvania, Ohio, California, and Texas each have more than ten centers (Tech Notes, 1991).

In 1983, the State of Ohio established the Thomas Edison Program that now includes eight Edison Technology Centers. These centers link Ohio research institutions with companies in a research consortium to turn technological advances into commercial products and processes. The Edison Pclymer Innovation Corporation (EPIC), the Edison Materials Technology Center (EMTEC), the Institute of Advanced Manufacturing Sciences (IAMS), and the Cleveland Advanced Manufacturing Program (CAMP) were of particular interest during this study. Recently, Ohio initiated OATC which is intended to transition technology from WPAFB to Ohio industry. This program will be mentioned later.

All these programs have been important to this study and the resulting program plans for three reasons.

(1) They provide a source of data on the impact of human issues on manufacturing programs.

(2) The research and experience established a correlation between human issues and the successes and failures of manufacturing modernization programs.

(3) Opportunities were discovered for cooperation and data exchange.

These programs are not described here; extensive material is available elsewhere. However, four programs are of particular interest because of their human-issue potential. They are:

(1) PRISSM (conducted by the MANTECH Directorate at WPAFB),

(2) ESPRIT,

(3) OATC, and

(4) the Computer-Aided Acquisition and Logistics Support (CALS) Research Program.

a. Program for Regional Improvement Services for Small Manufacturers

PRISSM is currently being conducted by the Manufacturing Technology Directorate of Wright Laboratories. The PRISSM Team is ready to begin what is called "the sixteen experiments." The objective is to develop methods and

supporting infrastructures as incentives to small companies to improve (i.e., to become more competitive). The program will operate in approximately 50-mile-radius regions across the country. The first region, which will be a prototype to prove the concept, will be Cincinnati-Dayton region.

A PRISSM Team of experienced personnel will study 16 small companies in the region. Eight will be chosen from among suppliers of an aerospace prime contractor. The Team will visit each company and study all aspects of its operation--financial, business policies, inventory, manufacturing, and technology from marketing to the shop floor. The PRISSM Team will report its findings and improvement suggestions to each company.

For the prototype region, the PRISSM Team consists of General Electric Company (GE), Industrial Technology Institute, Southwestern Pennsylvania Industrial Research Center, IAMS, and Lawrence Associates, Incorporated (LAI)--the PRISSM contractor. GE is the prime aerospace contractor in the prototype region. IAMS is an Edison Technology Center in Cincinnati and will be the operating center of the program in this region. All PRISSM Team members are under contract to LAI, under the large MANTECH support contract.

Each region will have the infrastructure to assist small companies as needed: chambers of commerce, state development programs, financial agencies, universities, etc. The PRISSM Team will supply the necessary operating and manufacturing experience.

PRISSM is planned in three phases.

Phase I: Develop plans and methods to enhance quality, cost, and schedule performance through infrastructure change and process modernization.

Phase II: Perform sixteen experiments to test and define the methodologies.

Phase III: Expand to other regions and develop a national support structure.

Phase I has just been completed and Phase II will begin shortly. Human issues are not yet included in the methodology, but since this is a

transition program, they are crucial to the success of the program and the modernization of the small companies involved.

b. European Strategic Programme for Research and Development in Information Technology

Human-centered AMS provides the focal point for the ESPRIT program. The Commission of ESPRIT has been a major catalyst for the development of a human-centered manufacturing system in an industrial setting.

An extensive HUFIT program has been established within ESPRIT. The program involves cooperation among 11 companies and research institutes in eight European communities. HUFIT has two major objectives.

(1) Establish an awareness program to acquaint the ESPRIT community with human-factors issues and facilitate the design of information technology products through application of human factors principles and techniques.
(2) Develop user interfaces.

A considerable effort has been expended by the European community to assess the current state of human-factors application in industry. For example, comprehensive studies were accomplished dealing with ergonomics in European information technology (conducted in the United Kingdom), and a comparative evaluation of human factors in Europe and worldwide (conducted in Germany).

Works such as those represented above sensitized the European community to the importance of human factors and human issues in industry. About the time the above studies were being conducted, the European information technology community established a consortium for a major project dealing with the application of human factors to information technology. The Stuttgart-based Fraunhofer-Institute fur Arbeitswirtschaft und Organisation assumed responsibility for the project. Several industrial and academic institutions were involved; therefore, one organization, the United Kingdom's HUSAT Research Centre, was given responsibility for managing the overall technical content. The vastness of the undertaking is

apparent in the areas included in the program:

(1) human-centered design with emphasis on total integration of human factors inputs into the design process,
(2) system-user interaction, and
(3) transfer of human factors knowledge throughout the European community.

HUFIT has resulted in several relevant studies. The scope and depth of information available through ESPRIT and its related programs are considerable and would be useful to the U.S. manufacturing community. Detailed descriptions of ESPRIT appear elsewhere; however, a brief description of HUFIT will help put ESPRIT in perspective.

HUFIT is considered a flagship program within ESPRIT. Contributing to the project were the HUSAT Research Centre, United Kingdom; the Fraunhofer-Institute fur Arbeitswirtschaft und Organisation, Germany; and Olivetti, Philips, Siemens, and others. The objective of the program was to provide the European information technology community with "a comprehensive human factors strategy from product conception to use."

The HUFIT approach is similar to a U.S. systems engineering process. The approach has a strong user orientation with interaction between the producer and the consumer. The role of human factors in the conceptualization and planning of the product follows when the specific needs of the consumer are understood. The human-factors role continues in each step of the product life cycle: development, testing, manufacturing, quality assurance, marketing, and product support.

HUFIT has delivered to European industry a "tool kit" designed to assist designers throughout their design process. The tool kit includes:

(1) Quick Ergonomic Design (QED) - a human factors primer,
(2) User Requirements - to assist in product planning,
(3) Specification and Design Tools - structure for crosschecking user/task requirements with function specifications,
(4) Documentation Toolset - structures user documentation,

(5) Human Factors (HF) Evaluation Toolset - a number of tools dealing with the development of specifications for user evaluation, and
(6) INTUIT - software that represents human-factors knowledge important to design.

The availability of HUFIT-generated data makes it well worth the investment required to access.

A similar objective with an alternate perspective and different implementation is given by William B. Rouse in Design for Success: A Human-Centered Approach to Designing Successful Products and Systems.

c. The Ohio Advanced Technology Center

OATC, a partnership between Ohio industry and WPAFB, was formed to enhance the world-class competitiveness of Ohio industry. "Wright-Patterson is one of Ohio's major technological assets in the global struggle for competitive advantage. Ohio's future will depend on its ability to apply technological advances in order to build superior products and services. The Voinovich-DeWine economic development strategy recognizes the tremendous potential of WPAFB as a key to regional and state economic development. The Ohio Advanced Technology Center, a manifestation of this policy, will contribute significantly to Ohio's economic security by invigorating and rejuvenating its industry" (OATC Plan, 1991).

The concept envisioned for OATC by the State of Ohio is to advantage itself by incorporating the professional/technical resources as integral to Ohio's strategy for economic development. The mission stated by the OATC Plan includes:

(1) Promote economic development in Ohio through the effective and timely application, transfer, and/or commercialization of technologies, know-how and other resources available at Wright-Patterson AFB.
(2) Build support for the mission of Wright-Patterson AFB, and for its goals, objectives, programs, and projects.

OATC is the implementation of the cooperation invited by federal policy and law. Quoting again from the OATC Plan:

> Congress has passed new laws and the President has directed implementation plans from the federal agencies, which will permit new levels of interaction between the federal laboratories and the private sector. Notable among these are the Stevenson-Wydler Technology Innovation Act of 1980 (PL 96-480) which mandated the transfer of federally originated technology to state and local governments and the private sector; the Federal Technology Transfer Act of 1986 (PL 99-502) which strengthens and replaces the Stevenson-Wydler Act, and also encourages the creation of centers and joint consortia (such as OATC) for cooperative research and development, common use of resources, and effective dissemination of technology and skills; and the 1987 Executive Order of then-President Reagan entitled, "Facilitating Access to Science and Technology." In this Order, the President encourages the Department of Defense to accelerate its efforts to make appropriate DoD technologies readily available to United States industries and universities. This order also suggests joint planning and funding between the federal government, the private sector, and state government for creating centers such as OATC. Recent regulations issued by the Department of Defense and the Air Force (i.e., AFR 80-27) are intended to implement the laws and the intent of the Congress, and accelerate the transfer of federally developed technology to the private sector.

Both the state and federal governments realize that the U.S. will be more competitive in the world market if the technology developed in our laboratories is used by our industry.

The OATC Board of Trustees membership will be leaders from industry, WPAFB, academia, and the financial community. Members of the greater-Dayton community are strongly represented on the Board; Lt Gen Thomas R. Ferguson, Jr., Commander, Aeronautical Systems Division (ASD), is an Honorary Trustee. These links ensure strong cooperation between Ohio communities and WPAFB. OATC will build on organizations currently operating in Ohio (e.g., the Thomas Edison Program) to facilitate rapid development. Dr. E. Frank Moore and EMTEC will provide the initial management to launch the OATC.

WPAFB technology appears to match the technology needs of Ohio. The Ohio Science and Technology Commission has recently eeveloped an agenda for Ohio's science and technology policy in the 1990s. The report of the Commission identified 25 key technologies for Ohio's future; more than half are major focuses for research at WPAFB. In the study conducted to formulate the OATC concept and plan, four particularly important technology groups were identified as common to Ohio industry and WPAFB:

(1) materials,
(2) advanced manufacturing,
(3) electronics, and
(4) information sciences

Hence, the technologies relevant to the growth of Ohio industry match the research priorities at WPAFB exceptionally well .

OATC is currently an emerging organization. State funding is being considered and initial implementation plans are being formulated. Candidates for programs, industry participants, and technologies are being solicited and examined.

The HUMANTECH study has found that human issues are crucial for two of the four technology groups highlighted for OATC: AMT and IT. There is an encouraging outlook and a realistic potential for human-issue cooperative programs between industry, academia, and WPAFB through OATC.

d. Computer-Aided Acquisition and Logistics Support

CALS, designed by the Department of Defense (DoD) for adoption by its prime and subcontractors, is finding some acceptance by non-DoD-related industries as well. Although the acronym CALS implies computers and automation, its prime objective is the promulgation and adoption of a standard by government and industry that permits effective information sharing. Developed by DoD and the defense industry, the CALS initiative focuses on the handling and integrating of digital, technical, and engineering information.

Considering the benefit to tens of thousands of U.S. industries and the need for improved productivity, CALS provides the welcome

structure for the digitization and sharing of information. Not only are large corporations embracing CALS-compliant automation, but the approach has been to consider the corporation and all its components (subcontractor, small supporting companies) as elements of a system. The system will work most effectively when the CALS environment has been adopted by all involved.

Senior members of the manufacturing community are already sensing that CALS will have major facilitative impact on day-to-day business activities. This is reflected in the strong position taken by corporations such as General Motors and Digital Equipment Corporation (DEC). Malcom D. Spence, a DEC executive, defines four main issues related to CALS:

(1) data exchange standards (a major DoD interest) item,
(2) concurrent engineering,
(3) total quality management (TQM), and
(4) advanced cost management.

The shared data is to be used in every phase of product life cycle, from conception through maintenance and support. The CALS concept of shared data becomes imperative if the above issues are to be undertaken. Equally important is the potential application of data developed under ESPRIT to CALS.

IV. MODERNIZATION PROCESSES

A. Introduction and Objectives

This section defines the terms and processes that reflect the human issues in modernization, and discusses modernization in terms of the processes of change, the attributes of the manufacturing state before and after change, and the change incentive. These processes, attributes, and incentives are related to quality production and the effect of MANTECH investments. Variables and measures are introduced, and some values are given to these human elements of MANTECH. Implementation methods are also discussed.

The objectives of this section are:

(1) provide a frame of reference within which modernization status and progress can be measured and described,

(2) introduce the notion of the multidimensional "state" of a business enterprise,

(3) expand the state model to include parameters that can be measured during modernization or change, and

(4) review possible transition processes that include human issues and considerations.

B. Business Operation Frame of Reference

The diagram in Figure IV-1 provides a frame of reference for the transition from current manufacturing systems to the goal state of lean manufacturing. Manufacturing before change is referred to as the initial state. The goal state is the desired state of operation that is productive, high quality, characterized by enthusiastic worker participation in all areas of the enterprise, and competitive in the market place.

The transition process moves an enterprise from current, "business-as-usual," conventional manufacturing to an AMS (i.e., the goal state). To understand the process and measure its implementation, definitions and measures of the current state and goal state are needed. Then management, after understanding the current state and defining a desirable goal state, can determine the steps needed to reach its objective.

Abstract Model

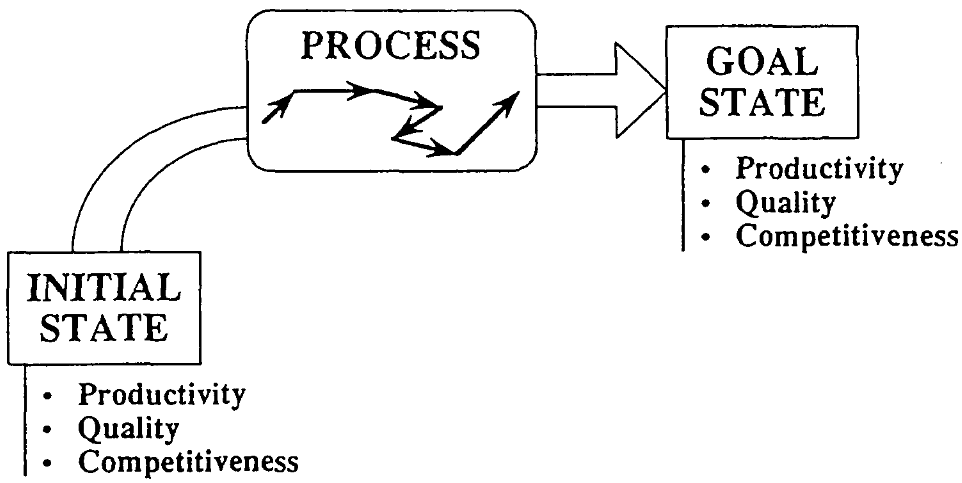

FIGURE IV-1. The Process of Change

Since modernization includes so many factors to be changed simultaneously, it is not a straight-line path to the goal state. The probability of reaching the intended goal state is low. Current research shows that the modernization path is precarious, with partial successes and partial failures. Adjustments and readjustments along the path reflect the difficulties company leaders have in changing the direction of the company and implementing necessary changes in culture. Modernization projects have a success rate of only about 30 percent. That is, in 70 percent of the cases workers revert to previous work habits and abandon the improved equipment or operations.

C. The Process of Change

The first step in the change process is to understand the current state and define the goal state. The process begins with:

(1) an understanding of the current manufacturing and non-manufacturing functions, as well as human forces (managerial, worker, environmental, and cultural) within the transitioning enterprise, and

(2) an understanding of the corporate goals that define the

intended AMS goal state.

The key issues in change are complex and require substantial attention from everyone in the enterprise including top management. The research indicates that this transition can be successful only if human issues are at the center of this manufacturing transition.

D. The Leadership Role

Modernization that intends to change an entire enterprise is a complex process. The transition from mass production to lean production changes culture, organizations, systems, traditions, and people. Its complexity makes it difficult to accomplish.

The leader of a business entity is the only person who can elect such a large change. This CEO or General Manager (whoever has sufficient authority to initiate the change) will have to manage the change and change process. Unfortunately, the CEO often has a considerable investment in the current culture and is ambiguous or hesitant about change. Although, the CEO may want to be more competitive and would like enthusiastic and empowered employee teams, higher quality, and order-of-magnitude lean-manufacturing improvements, he may not want change to affect his own domain. That is, he doesn't want to change himself. If this occurs, the organization's change advocate is also change's worst enemy.

It is difficult to lead a cultural change. Culture is tradition; the way things are done in the enterprise. The CEO cannot dictate the change. He cannot suddenly tell people to do things differently and expect them to obey. The enterprise doesn't necessarily have the knowledge, intention, processes, or the new culture to do things differently. The knowledge, processes, roles, responsibilities, orientation toward quality and customer needs, working differently with teams and colleagues -- all these elements must change together. Just one change will fall victim to the traditional pressures; it will not be the beginning of a cultural change, just a perturbation of normalcy.

The complexity of the cultural change means everything must change or nothing will change. The change depends on people. People in the enterprise must do

things differently, implement the change, and begin working with each other in a different tradition. Thus, the CEO must lead, but everyone must change.

The CEO and the orchestra conductor share the same role; they are both leaders, but neither actually makes the product. The CEO is pictured in Figure IV-2.

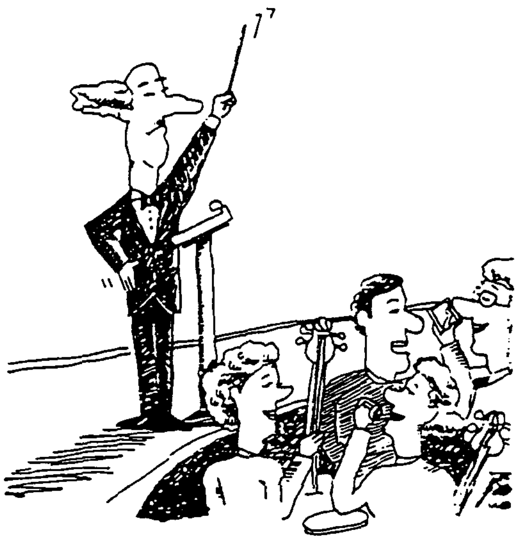

FIGURE IV-2. An Organizational Leader, But the CEO Doesn't Make Music

The conductor, while "in charge," does not play music. Corporate leaders often attempt to dictate cultural change, insist people change, and make the music. The inconsistency is that they are dictating employee empowerment but demonstrating the opposite as a success model. Notably, employee empowerment is required by lean manufacturing.

The conductor can inspire, influence, encourage, provide incentives, establish goals, select the music, and lead. He does not have an instrument with which to make music--the musicians in the orchestra play the instruments. If the culture is to change, it is the musicians who must work as a team, choose continual improvement, improve the way things are done, and cooperate with the conductor. These are not changes that can be dictated. The musicians must choose to change.

Thus, for change to happen in a manufacturing enterprise, the corporate leadership must unambiguously select change and provide the leadership consistent with the desired goal state and culture. Then, everyone--including the corporate leaders--must change. Employee empowerment cannot be dictated; therefore, management must change to provide the necessary leadership. Employees must then choose to adopt a new culture, i.e., a new way to conduct the business of the enterprise.

E. Independent Parameters of Change

Management must provide the leadership for change. What independent parameters can management direct? What are the independent variables that it can control to lead and coax the manufacturing enterprise into adopting lean manufacturing with increased productivity, quality, profit, and world competitiveness?

The results of the MIT Commission on Industrial Productivity (Berger et al., 1989) include five interconnected imperatives that the Commission believes must form the core of any productivity effort at the national or local level.

(1) Invest more heavily in the future. "This means investment not only in tangible factories and machinery but also in research and, above all, in human capital."

(2) Develop an "economic citizenship" in the work place. "Companies will no longer be able to treat employees like cogs in a big and impersonal machine.... If people are asked to give maximum effort and to accept uncertainty and rapid change, they must be full participants in the enterprise rather than expendable commodities."

(3) Make a major commitment to mastering the new fundamentals of manufacturing. "Manufacturability, reliability, and low cost should be built into products at the earliest stages of design."

(4) Strive to combine cooperation and individualism. "The nation's culture has traditionally emphasized individualism, often at the expense of cooperation. Yet, in the best United States companies (as in other societies), group solidarity, a feeling of

community and a recognition of interdependence have led to important economic advantages.... To this end, steep organizational hierarchies, with their rigidity and compartmentalization, should be replaced with substantially flatter organizational structures...."

(5) Expand the outlook beyond current boundaries. This is essential to "compete successfully in a world that is becoming more international and more competitive.... What Americans must do is determined decreasingly by what they wish to do and increasingly by the best practices of others."

These "imperatives" summarize methods the CEO may use to orchestrate movement toward lean manufacturing (i.e., the goal state).

Refer again to the model of change (Figure IV-1). For the initial state, goal state, or any state in between (on the process path), the independent parameters are:

(1) Business Goals and Objectives,
(2) Personnel Policies,
(3) Culture,
(4) Environmental Factors, and
(5) Fiscal Accounting Practices.

These parameters, both independent and dependent, were chosen by a clustering process. As the study was conducted, a list was compiled of the terms and variables used by authors and managers to describe their processes, thoughts, and successes. The terms were grouped into affiliated clusters termed parameters. The parameter names were chosen to be representative of the terms, variables, measures, and issues contained in the cluster.

The dependent parameters are related to the independent parameters of the enterprise. The dependent parameters of the enterprise are:

(1) Productivity,
(2) Quality, and

(3) Competitiveness.

The relationship between the independent and dependent parameters is shown in Figure IV-3. More detail on each parameter is given later.

Technology is not listed as an independent variable. This may seem to be an oversight since the study topic is technology and manufacturing modernization. Technology is controllable by management; that is, management can purchase or install new technology or equipment. Therefore, should it be an independent variable? There are many cases in which the addition of technology did not change the productivity, quality, or competitiveness. Thus, technology is not an independent variable.

When the business objective is to modernize (i.e., become more competitive), management can begin by controlling the independent variables. It is often a mistake to purchase or install technology as the initial modernization step; however, technology will undoubtedly be part of the modernization implementation. All the examples that form the basis for this report are high technology examples; that is, they include extensive AMT and IT. Clearly, technology in lean manufacturing is extensive.

$$\text{Actual State} = \text{A Complex Function of} \left(\begin{array}{l} \text{Business Goals and Objectives} \\ + \text{ Personnel} \\ + \text{ Culture} \\ + \text{ Environment} \\ + \text{ Fiscal Accounting Practice} \end{array} \right)$$

- Productivity
- Quality
- Competitiveness

FIGURE IV-3. The Dependent Variables are Functionally Related to the Independent Variables

The CEO or leader can control only the independent parameters. He or she can choose the business goals, change the personnel policies, select elements of a particular business culture, and change environmental factors. For example, the CEO can decide to shift more decision-making power to workers, establish rewards for excellence, provide more training opportunities, or involve employees in the operational decisions of the enterprise.

On the other hand, the CEO does not control the dependent parameters. For example, he or she cannot dictate the productivity of the enterp ise but can manipulate the independent parameter to encourage employees to be more productive. The workers must choose and be more productive, to pay more attention to quality. It is the workers choice, not the CEO's.

This model permits the status of current manufacturing facilities to be evaluated and allows those parameters essential to the transition from the current state to the goal state to be incorporated within the statement of corporate goals. Thus, a

plan to change to the goal state can be written and implemented.

F. Definitions of Model Independent Parameters

Definitions and measurable variables for each independent parameter are presented. The characteristic values for each variable are also given. Process identification is idiosyncratic to a given industry and must be evaluated within that context.

Each of the five independent parameters is composed of several elements. For example, to help delineate a modernization program, Business Goals and Objectives would incorporate specifics in all domains considered important to the future of the business enterprise.

Although human issues are an essential part of both Business Goals and Objectives and Fiscal Accounting Practices, neither will be discussed further here. Personnel Policies, Culture, and Environmental Factors will be described in the following tables.

The Personnel Policies parameter consists of the four variables listed in Table IV-1. Associated with each variable are measures of that variable. For example, diversity is a measure of job definition and training. On the other hand, personnel policies related to lean manufacturing emphasize training and hold multifunctional workers and problem-solvers in highest regard.

TABLE IV-1. Personnel: Parameter Description

Variable	Measures
Diversity	• Multifunction worker rate • Number of job classifications
Commitment/Cooperation	• Willingness to share information • Willingness to improve quality • Rate of absenteeism
Responsibility	• Number of tasks worker is responsible for
Problem Solving Capabilities	• Experience • Education

Each variable in Table IV-1 also appears in Table IV-2. This table lists characteristic values for each variable of the Personnel parameter. Again, using diversity as the example, in mass-production manufacturing there are numerous job classifications and it is difficult for workers to move to another job. In lean-production systems, workers spend more time and energy learning problem-solving and can move more easily from one job to another.

TABLE IV-2. Personnel: Characteristic Variable Values

Variable	Variable Values	
	Initial	Goal
Diversity	• Multifunction worker rate <60% (Monden, 1983) • Many job classifications	• Multifunction worker rate 100% (Monden, 1983) • Few job classifications
Commitment/Cooperation	• Few suggestions • Many defects in finished product • High rate of absenteeism	• Many suggestions • No defects in finished product • Low rate of absenteeism
Responsibility	• Few tasks worker is responsible for	• Many tasks worker is responsible for
Problem Solving Capabilities	• Few years of related experience • Few years of education or training	• Many years of related experience • Many years of education or training

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The next pair of tables defines the Culture parameter. The Culture parameter variables are listed in Table IV-3. Using worker confidence as an example, an important measure demonstrating the difference between mass production and lean production is the level of trust in management. In mass production, there is little confidence and sometimes an adversarial relationship. In lean production, the workers have confidence in management and management has confidence in the workers. Consequently, employees are empowered with much more authority than would be tolerated otherwise.

TABLE IV-3. Culture: Parameter Description

Variable	Measures
Reporting Structure	• Amount of autonomy at lowest level • Number of authority levels
Team Work	• Amount of participation in group quality teams
Worker Confidence	• Level of trust in management • Percentage of layoffs or firings • Employee turnover rate
Reward Structure	• Salary criterion • Number of suggestions rewarded • Amount of verbal recognition • Number of achievement awards given
Assembly Layout	• Degree of feedback received by worker
Department Proximity	• Distance between entities within operating unit

Table IV-4 gives some characteristic values for each culture parameter variable.

TABLE IV-4. Culture: Characteristic Variable Values

Variable	Variable Values: Initial	Variable Values: Goal
Reporting Structure	• Low number of changes made by worker • Many levels of authority	• High number of changes made by worker • Few levels of authority
Team Work	• Low number of participants in quality teams	• High number of participants in quality teams
Worker Confidence	• Many challenges of management decisions • High number of layoffs or firings • High turnover rate	• Few challenges of management decisions • Low number of layoffs or firings • Low turnover rate
Reward Structure	• Criterion: job title • Low number of suggestions rewarded • Low amount of verbal recognition • Low number of achievement awards	• Criterion: seniority • High number of suggestions rewarded • High amount of verbal recognition • High number of achievement awards
Assembly Layout	• No feedback to worker	• High amount of feedback to worker
Department Proximity	• Large distance between entities within operating units	• Small distance between entities within operating units

The final independent parameter management can control is Environment. The Environment parameter is defined in Table IV-5. The variables that make up the Environment parameter and some of their characteristic measures are listed.

TABLE IV-5. Environment: Parameter Description

Variable	Measures
Plant Layout	• Process flow
Machine Layout	• Production balance between stations • Worker isolation
Storage Space	• Amount of storage space available
Lighting	• Illumination
Temperature	• Heat index
Information Display Terminal	• Availability
Noise	• Noise level

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Table IV-6 lists some characteristic values of the Environment parameter. In lean-manufacturing states, workers are informed, considered an important part of the manufacturing process, and encouraged to work as members of a team.

TABLE IV-6. Environment: Characteristic Variable Values

Variable	Variable Values	
	Initial	Goal
Plant Layout	• Long time for parts transportation within plant	• Short time for parts transportation within plant
Machine Layout	• Unbalanced production between stations • High amount of worker isolation	• Balanced production between stations • No worker isolation
Storage Layout	• Large amount of storage space	• Small amount of storage space
Lighting	• ---	• 500 - 1000 lux
Heat	• ---	• <81 degrees F
Information Display Terminal	• Not available	• Available
Noise	• ---	• <80 dB for 8-hour work day

In each case, human issues are crucial to each independent parameter and essential to many dependent parameters. Humans are part of every facet of manufacturing.

G. Transition Process

Refer again to Figure IV-1, depicting the two manufacturing states and the transition process leading from one to the other. The state of the manufacturing system was defined in terms of the dependent parameters listed next to the circles. The independent parameters, which may be under management control, were defined in Tables IV-1 through IV-6 giving variables, measures, and some characteristic values indicative of the type of manufacturing or production system. Now that these parameters have been established the transition process can be discussed.

Many transition processes are being promoted to change and modernize manufacturing operations, empower workers, or improve quality, productivity, and competitiveness. TQM is being used in ASD and the affiliated business community. Peter Scholtes (1988) and his associates provide a prescription for creating and empowering teams and building a quality organization based on teamwork. J. M. Juran (1989) is one of the best known names in the field of improving quality. These and other references provide rules, techniques, reference material, admonitions to improve, and encouraging examples.

However, failures are also reported in the literature (see Section III.B.1). In general, modernization programs are only 30 to 50 percent successful. That is, after the studies have been completed, equipment purchased, software written, equipment delivered and installed, and people trained, more than half the time employees revert to previous methods and processes. The modernization did not take; it did not improve the productivity or quality; it was a waste of money and effort.

There are numerous methods for improvement. None are perfect for everyone and it is difficult to choose. Not even the most enthusiastic champion of any method can assure success (i.e., improved quality and productivity)--there are too many counterexamples. Of the numerous change methods available, three will be discussed.

Jack Byrd (1991) believes the key to modernization is to change the business culture. Since he approaches change from a social change perspective, he finds leadership models for corporate culture change in leaders of social change such as Martin Luther King and Ralph Nader. His strategy is being adopted and advocated by the The Concurrent Engineering Research Center. Figure IV-4 depicts Byrd's change strategy. Figure IV-5 is his suggested plan of action.

CHANGE STRATEGY

• VISION •

STATEMENT OF WHERE THE ORGANIZATION IS GOING AND WHAT IT VALUES

• INITIAL REBELLING ACT(S) •

SOME HIGHLY VISIBLE ACTION THAT SENDS THE MESSAGE THAT CURRENT PRACTICES ARE NO LONGER ACCEPTABLE

• BUILDING A BELIEVER NETWORK •

CREATION OF A CORE GROUP OF INDIVIDUALS WHO SUPPORT THE VISION AND ARE WILLING TO PUT THEMSELVES AT RISK TO ACHIEVE THE VISION

• VALUE SHAPING EVENTS •

DEMONSTRATIONS TO EVERYONE THAT IMPROVEMENT IS POSSIBLE EVEN IN ACTIVITIES THAT HAVE LONG RESISTED CHANGE

• SPREADING THE WORD •

USE OF INITIAL SUCCESSES TO TEACH AND MOTIVATE OTHERS TO WORK TOWARD THE VISION

• MOMENTS OF TRUTH •

MEETING CHALLENGES TO THE VISION AND VALUE SHAPING ACTIVITIES

• KEEPING THE FAITH •

BUILDING OF OWNERSHIP AND ABILITY TO FULFILL THE VISION EVEN AFTER THE VISIONARY HAS GONE

FIGURE IV-4. Byrd's Change Strategy

PLAN OF ACTION

• CHARACTERIZATION •

STRATEGY, OPERATIONS, SYSTEMS

• BENCHMARK COMPETITIVE POSITION
• CHARACTERIZE PRODUCT DEVELOPMENT PROCESS AND ENVIRONMENT
• REVIEW BUSINESS PRACTICES AND METRICS
• IDENTIFY KEY LEVERAGE POINTS IN VALUE CHAIN
• ASSESS SYSTEMS TECHNOLOGY AND TOOLS

• VISIONING •

BUSINESS PRACTICES, ORGANIZATION, SYSTEMS

• CREATE PRODUCT DEVELOPMENT VISION
• DEVELOP TRANSFORMATION STRATEGY AND TACTICS
• BUILD EXECUTIVE COMMITMENT AND CONSENSUS
• DESIGN MANAGEMENT SYSTEMS AND ROAD MAP
• SET ORGANIZATIONAL GOALS AND METRICS

• CHANGE MANAGEMENT •

MIGRATION PATH, TEAM BUILDING, TECHNOLOGY

• IMPLEMENT QUICK FIXES
• DEVELOP STEERING COMMITTEE AND FACILITATORS
• PILOT INTEGRATED PRODUCT DEVELOPMENT DESIGN TEAMS
• ESTABLISH AND TRAIN WORK REDESIGN TEAMS
• INTRODUCE NEW TECHNOLOGY AND UPGRADE SYSTEMS
• INSTITUTE NEW PERFORMANCE MEASUREMENT AND REWARD SYSTEMS

• ONGOING •

• EVALUATE AND ADJUST VISION
• MONITOR PERFORMANCE METRICS AND PROCESS
• SHARE AND REWARD TEAM SUCCESSES
• CHALLENGE

FIGURE IV-5. Byrd's Plan of Action

William Rouse (1991) uses a systems engineering approach to what he calls a human-centered design. His strategy relates more to the design and concurrent engineering aspects of modernization. Figure IV-6 displays his process.

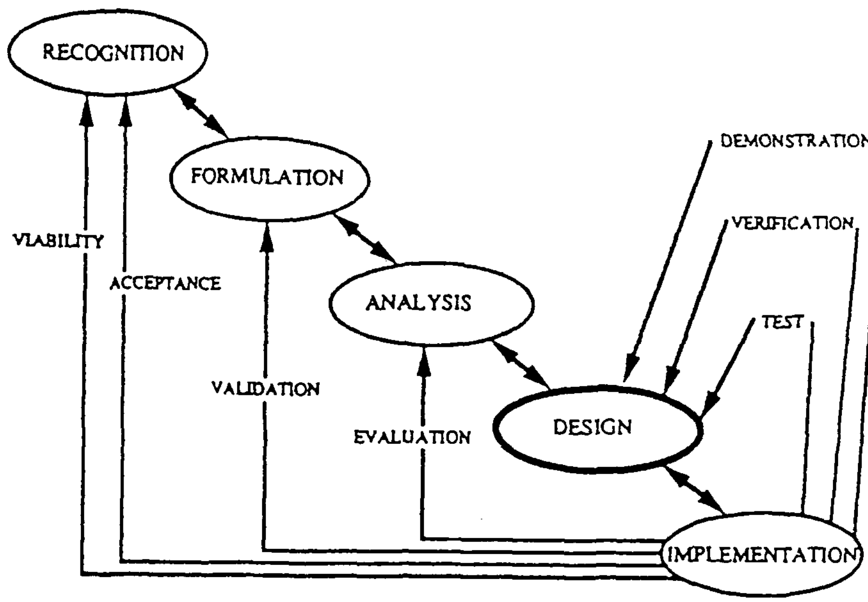

FIGURE IV-6. Rouse's Human-Centered Design Process

PRISSM, discussed in Section III.C.2.a, has produced a change process. Phase I of PRISSM was conducted to eevise ways to convey technology and methods of change to small business. Human issues are not yet part of the change process that will be applied in Phase II.

Seemingly, no formalized change process incorporates the human issues and perspectives presented in this report. However, we believe that some of the popular methods could be augmented, by incorporating management of the independent variables defined in Section IV, to provide a robust modernization methodology. The development and application of such a method, titled the HUMANTECH Change Process, is proposed in the Recommendations (Section VI) of this report.

V. CONCLUSIONS

The intent of this study was to show that human issues are crucial to AMT and IT, to generate the rationale, and develop a plan to augment current MANTECH practice with beneficial human issues and considerations.

A. Human Issues Crucial to MANTECH and Integration Technology

Human issues are crucial to MANTECH and manufacturing modernization. There is extensive evidence of uhis in the literature, the performance and evaluation of U.S. modernization programs, the comparison with similar programs overseas, and the opinions of industry leaders in the U.S. and abroad. Some of this evidence has been compiled in this report.

The first question we answered is: Which human issues are important? We developed a model of the modernization process that defines the independent and dependent parameters of the modernization change process. These parameters and their variables identify the particularly important human issues.

The second question--How should human considerations be systematically incorporated into MANTECH and IT--was not answered in this report because the change process is not yet developed. There is a need to understand and define a HUMANTECH change process to be a part of manufacturing modernization (see Figure IV-1). A recommendation to develop and apply this process is contained in the first three specific recommendations in Appendix.

B. Improved Manufacturing Competitiveness

There is an acute need to improve U.S. manufacturing competitiveness. Some social scientists and business leaders believe the U.S. high standard of living is in jeopardy in a worldwide race for competitive manufacturing. Human resources--as well as natural, technical, and financial resources--will be essential to the competition.

Transition of U.S. industry to lean manufacturing is a major challenge. Section VI presents recommendations for the next step, including human issues in manufacturing modernization and MANTECH.

VI. RECOMMENDATIONS

An objective of this study was to develop a plan to incorporate human issues in MANTECH. That plan, the HUMANTECH Program Plan, (provided in the Appendix) is the substance of our recommendations. Our recommendations are as follows.

(1) Define the HUMANTECH Change Process by which human issues are incorporated into the change or modernization process (Figure IV-1). This recommendation is implemented in the first task of the Appendix.

(2) Apply and test the HUMANTECH Change Process with applications to the ALCs and industry. PRISSM is currently a particularly enticing industry opportunity.

(3) Exchange technology and experience with Ohio industry. OATC has been formed to share technology and experience between WPAFB and Ohio industry. The State of Ohio will help fund the technology transition and exchange.

(4) Establish a HUMANTECH development facility. There is no home for human issues in HUMANTECH in the U.S. There is no place where technology demonstrations, feasibility studies, integration displays, or standards testing can be accomplished in which human issues are primary. Since human considerations are of such fundamental importance, a facility dedicated to human issues should be established.

(5) Conduct a workshop on activity accounting and measuring the improvements provided by manufacturing modernization. Throughout this study, difficulties have been identified in measuring the value of modernization with the conventional accounting practice. To respond to the difficulty, industry is moving toward activity accounting. This workshop would establish the place of human issues and HUMANTECH in the accounting revolution.

(6) Initiate a HUMANTECH Exploratory Development program. Fundamental data are needed to apply human issues in manufacturing. It is our view that some of the needed eata will be available from foreign research and development programs currently being conducted.

The race for quality and productivity, now underway, will be a never-ending process. World competitors will continually seek additional improvements. According

to "Newscope" (Industrial Engineering, April 1991), the Manufacturing 21 Report: The Future of Japanese Manufacturing announces that Japanese companies are "working to develop post-JIT [Just-in-Time] manufacturing, highly flexible to change, decentralized management, integrate software, and attract bright young people to manufacturing enterprises.... A metabolic system that can grow and renew itself will be needed in the coming years."

"Newscope" cites four key areas that require attention to evolve manufacturing systems toward effective 21st century competitiveness. Three of these key areas focus on human issues and the involvement of people in manufacturing.

(1) A more creative labor force. "Focus of productive activities shifts from the shop floor to the work force preparing for production." Traditional human resource management systems must be redesigned to stimulate quality and productivity in tomorrow's work force.

(2) Global corporate development. People must develop strategies and tactics from a global perspective, operating on a common understanding--a practice referred to as "management by people."

(3) A new paradigm. "A practical approach to 'small is beautiful' will replace large-scale manufacturing. The new way must integrate high technology, information, communications technology, and intellectual creativity."

(4) Beyond continual improvement. More JIT and more Total Quality Control (TQC). Manufacturers need scenarios describing large leaps into the future as well as small steps toward improvement.

Throughout this report, human issues have been shown to be crucial to MANTECH and IT. In the future, human issues will be even more important in manufacturing and in determining the leaders in world competition.

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Appendix

HUMANTECH Program Plan

(Human Issues in Manufacturing Technology Plan Recommendations)

Numerous countries, U.S. government agencies, universities in this country and abroad, industry consortiums in several countries, and individual industries are conducting programs to improve their competitive edge in world manufacturing. Only a few of these efforts have included human issues as a substantial program element; however, human issues play a crucial role in the success of competitive manufacturing. They are essential to the very nature of manufacturing, and are necessary to attain and maintain a competitive edge. This reality is gradually being taught, throughout the world, by manufacturing successes and failures. Data, processes, costs, walues, metrics, and design experience are needed to incorporate human issues into manufacturing modernization efforts. The urgent need is recorded in both the literature and current manufacturing experience.

The HUMANTECH Plan, as presented herein, is designed to respond to the urgent need to systematically incorporate human issues into Manufacturing Technology (MANTECH) and Integration Technology (IT) practice. Figure A-1 is a HUMANTECH Roadmap.

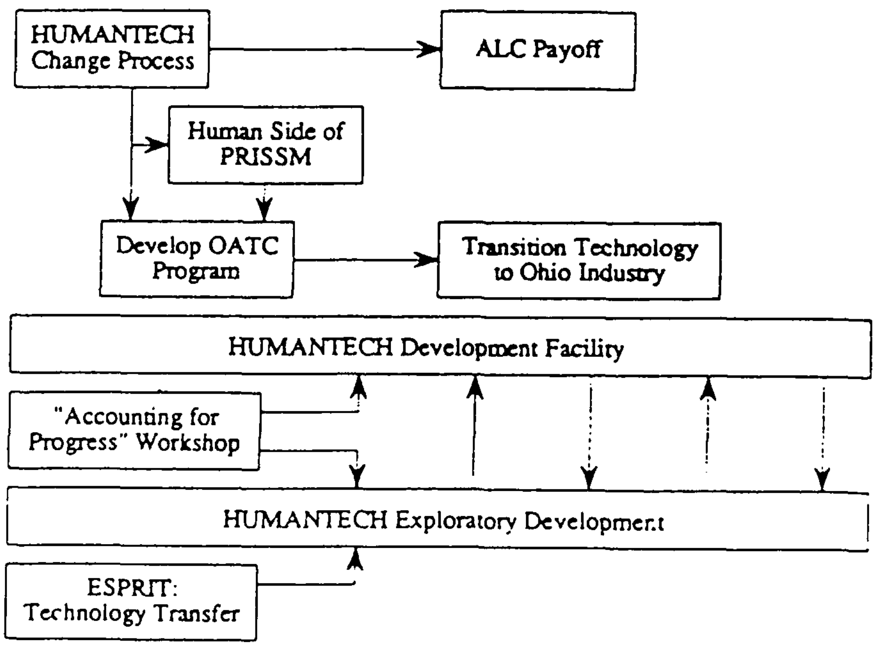

FIGURE A-1. HUMANTECH Roadmap

Develop the HUMANTECH Change Process

Although there are several champions of change and modernization, there is no formal change process that incorporates human issues. The first task of the HUMANTECH Program Plan would begin with the current change processes and develop them into a HUMANTECH change process.

Objective

Develop the rules and steps of the HUMANTECH change process and test with industry or Air Logistic Center (ALC) experience.

Approach

Current change processes will be augmented to include human issues by using the change model developed in Section IV of the Macauley Brown, Inc., report entitled, "Human Issues In Manufacturing Technology" as a basis. Current qrocesses do not deal with the independent parameters necessary to incorporate human issues and concerns.

Develop the HUMANTECH Change Process. The independent parameters of the model would be used to identify needed additions to current processes. The augmented rules and steps would be documented.

The Human Side of (PRISSM)

PRISSM will provide valuable guidance for human issues research. Knowledge gained from current and past efforts will serve as the linchpin for future efforts.

PRISSM is currently being conducted by the Manufacturing Technology Directorate of Wright Laboratories. The PRISSM Team is now ready to begin what is called "the sixteen experiments." The objective is to develop methods and supporting infrastructures to provide incentive to small companies to improve and become more competitive. The program will operate in regions of approximately 50-mile radius all across the country. The first segion, which will be a prototype to prove the concept, will be the Cincinnati-Dayton region.

A PRISSM team of experienced personnel will study sixteen small companies in the region. Eight will be chosen from among suppliers of an aerospace prime contractor. The PRISSM Team will visit each company and study all phases of the company's operation: financial, operations, inventory, manufacturing, and technology from marketing to the shop floor. The PRISSM Team will report its findings and improvement suggestions to the company.

The PRISSM team for the prototype region consists of General Electric Company, Industrial Technology Institute, Southwestern Pennsylvania Industrial Research Center, Institute of Advanced Manufacturing Services (IAMS), and Lawrence Associates Incorporated (LAI, the PRISSM contractor). GE is the prime aerospace contractor in the prototype region. IAMS is an Edison Technology Center in Cincinnati and will be the operating center of the program in this region. All the PRISSM team members are now under contract to LAI as part of the large MANTECH support contract.

Each region will have the infrastructure to assist small companies as needed: chambers of commerce, state development programs, financial agencies, universities, etc. The PRISSM team will supply the operating and manufacturing experience that may be needed.

The PRISSM program is planned in three phases.

Phase I: Develop plans and methods to enhance quality, cost, and schedule performance through infrastructure change and process modernization.

Phase II: Perform sixteen experiments to test and refine the methods.

Phase III: Expand to other regions, and develop a national support structure.

Phase I has just been completed; Phase II will begin shortly. Human issues are not yet included in the methodology, but since this is a transition program, they are crucial to the success of the program and the modernization of the small companies involved.

Objective

(1) Include HUMANTECH as a discipline in PRISSM.

(2) Validate the change model and the conclusions of this study with small business experience.

(3) In conjunction with the PRISSM Team, develop a method for transition to lean manufacturing that includes all the disciplines.

Approach

(1) Participate as a PRISSM Team Member throughout Phase II.

(2) Write a final report on the HUMANTECH-PRISSM effort.

HUMANTECH: The ALC Payoff

ALCs are large manufacturing, remanufacturing, and refurbishing enterprises necessary to maintain Air Force aircraft and other inventory. Since efficiency and quality are as important to the ALCs as to other U.S. manufacturing enterprises, similar modernization and technology application programs are required to maintain efficiency and quality. Human issues also play an important role.

The intent of an effort under the HUMANTECH Program Plan would be to study the human-issue involvement, influence, and significance in ALC modernization programs. The study would concentrate purely on the human-issues aspect of modernization.

Examine the human-issues contribution to ALC modernization programs and processes, and relate performance and notable successes to the human-issues disciplines. Develop conclusions regarding the dependence of ALC modernization programs on human issues, and the processes and values involved.

This effort would be a field study of ALC transitions from mass or craftsman production to lean manufacturing. A small first effort is recommended to develop and demonstrate the methods in one or two carefully chosen ALC examples. A successful first effort could motivate a larger effort to study and suggest improvements to the ALC modernization programs.

Approach

(1) Examine specific ALC programs using the methods devised above.

(2) Describe relationships between the independent parameters and dependent measures of the modernization effort. Independent parameters and quality measures would be defined in the report as the input and output of the manufacturing operation. Each independent parameter has a human-issue ingredient.

(3) Report the findings and provide recommendations.

Ohio Advanced Technology Center (OATC)
HUMANTECH Technology Transition

OATC was formed in January 1991 as part of the economic development plan for Ohio. Funding for the Center is expected in the current Ohio state appropriations cycle.

The mission stated by the OATC Plan (1991) is:

(1) Promote economic development in Ohio through the effective and timely application, transfer, and/or commercialization of technologies, know-how, and other resources available at Wright-Patterson [Air Force Base (WPAFB)].

(2) Build support for the mission of [WPAFB], and for its goals, objectives, programs, and projects.

OATC is the implementation of the cooperation invited by federal policy and law. Both the state and federal governments realize that the U.S. will be more competitive in the world market if the technology developed in the WPAFB laboratories is used by U.S. industry in its quest for manufacturing quality and excellence.

Objective

Select an activity, such as the HUMANTECH Change Process, and establish a cooperative effort through OATC to work with the MANTECH Directorate of the Wright Laboratory, the Logistics Division of the Armstrong Laboratory, and Ohio industry through the OATC.

Approach

Propose a joint effort between OATC and DoD affiliates.

The HUMANTECH Development Facility

There is no facility in the U.S. in which the study of human issues plays a predominant or even prominent part. The HUMANTECH Development Facility would be the central focus for human issues in MANTECH in this country.

Objective

Develop a HUMANTECH facility to assess and demonstrate the role of the human in a controlled, realistic advanced manufacturing system (AMS) environment. Since the human is a subsystem of the manufacturing enterprise, it is important that the human be considered in manufacturing modernization. The purpose of the HUMANTECH Development Facility would be to test and demonstrate integrated and integrating technologies in conjunction with human issues.

Approach

Propose a HUMANTECH Development Facility that will:

(1) be an industry training center to focus on small group interaction techniques;

(2) provide a continuous Air Force symposium on human issues in lean manufacturing;

(3) provide a demonstration/experimentation setting in which human issues are a central controlled part of the operation; and

(4) develop and test standards which impact the human, human performance, safety, and training in manufacturing environments.

HUMANTECH: Accounting for Progress

Accounting practice is not a human issue; measuring the value and contribution of human issues in manufacturing modernization is. This task is to define the human issues and interest in the new accounting practices being developed.

Justifying the cost of modernization has been an obstacle to modernization in the U.S. U.S. accounting systems burden labor with overhead costs. Then, to decrease costs, management reduces labor. Neither improved production nor competitive manufacturing result. Labor is reduced based on an artifact in the accounting system that points to labor rather than the indirect activity costs as the culprit which saps efficiency. The accounting system does not reflect or convey the correct state of the enterprise and continues to mislead U.S. industry decision-makers.

More specific accounting methods are needed to reflect what is happening to the enterprise (Drucker, 1990). The key is activity accounting that reflects the cost of activities, defines performance as productivity, and conceives of manufacturing as a sequence of physical activities that add economic value to materials.

The barriers to activity accounting are both bureaucratic and procedural. Another problem is changing the basic procedures of the manufacturing system to a new system with new operational measures, while maintaining some control during the transition.

Objective

Conduct a workshop on activity accounting and the measures of lean manufacturing and modernization. Examine activity accounting, or alternatives, from the points of view of industry and the ALCs to identify sensitivities and barriers, determine methods for change, and understand the HUMANTECH contribution to activity accountiog. Provide proceedings that document the views and conclusions of the workshop.

Approach

The three-day workshop would be held in Dayton. The first two days would be invited papers and panel discussions; this would be open to the public. The final day would be a committee meeting to draft the conclusions and recommendations.

The topic would be activity accounting, but the discussion would focus on the management of change. The theme would cover, but not be limited to, the list of parameters and measures developed in the Methodology Section (Section IV) of the Macauley Brown, Inc., report entitled, "Human Issues in Manufacturing Technology." Proceedings would be published.

HUMANTECH Exploratory Development Recommendation

Throughout the HUMANTECH study, there were clear needs for human-issues data and know-how. This task would fill some of those needs.

Objective

(1) Develop human factors engineering inputs to AMS (such as span-of-interest and motivation displays).

(2) Research the influence of operational corporate cultures on the transition to AMS.

(3) Develop a process to use human issues in the design and planning of manufacturing modernization; for example, determine their most effective role, what to automate, the process of design, etc.

(4) Define the training role in the manufacturing design process (i.e., is it part of design, operation, or culture).

(5) Develop concepts of job design and redesign for lean manufacturing (e.g., how to move work force as continued improvements are realized and how to combine functions to provide full workload for each employee).

(6) Develop measures to evaluate human-centered and performance data for lean advanced manufacturing technology (AMT) risk evaluation. The development could begin with the attributes and model described in Section IV of the Macauley Brown, Inc., report entitled, "Human Issues in Manufacturing Technology."

(7) Develop manufacturing situation awareness--how to design closed-loop information systems of the kind used in manufacturing cells. In lean manufacturing, there is a requirement uo provide current statistical information to manufacturing employees at their workstations. There are two steps in the needed development: determine the relevant metrics, and choose a way to display the information that supports and motivates the continual improvement process.

(8) Develop HUMANTECH standards (e.g.,teach pedants, control panels, emergency procedures) and relate to performance, safety, efficiency, training, and motivation for improved performance.

The European Strategic Programme for Research and Development in Information Technology (ESPRIT): Technology Transfer

ESPRIT has a large component called Human Factors in Information Technology (**HUFIT**). Eleven companies and research institutes in eight European countries are participants.

HUFIT has two major objectives. First, it aims to improve the IT products design by increasing awareness of human factors issues and providing methods and tools for a user-oriented design. Second, it intends to further develop user-interface techniques, especially for multimedia and multimodal interfaces by providing tools for prototyping and implementing these interfaces.

HUFIT has generated some data on human-centered design and human-centered organization of manufacturing.

Objective

Establish working relationships and information exchanges with principals of HUFIT.

Approach

Develop and establish working links and exchanges to ESPRIT and HUFIT. ESPRIT is more advanced than programs in the U.S., and some of the results and conclusions are already being applied in industry. Begin with a study of HUFIT documents and results, and initiate correspondence on shared interests. Exchange ideas and, if useful, propose to share development projects.

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